APPENDIX II

KLOHN LEONOFF LTD., SEDIMENT TRANSPORT ANALYSIS FOR CLINTON AND WOLVERINE CREEKS, APRIL 23, 1985

NORECOL ENVIRONMENTAL CONSULTANTS LTD., CLINTON CREEK ASBESTOS MINE AQUATIC IMPACT ASSESSMENT, APRIL 11, 1985

REPORT ON SEDIMENT TRANSPORT ANALYSIS

PROJECT:	CLINTON CREEK ASBESTOS MINE WOLVERINE CREEK TAILINGS PILES
LOCATION:	YUKON TERRITORY
CLIENT:	BRINCO MINING LTD.

OUR FILE: PB 3169 0301 APRIL 23, 1985

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APPENDICES

DRAWINGS

1. INTRODUCTION

This report presents the results of sediment transport analyses carried out by Klohn Leonoff Ltd. on Wolverine and Clinton Creeks downstream of the Wolverine Creek tailings piles. The work, as proposed in Klohn Leonoff's letter of December 11, 1984, was carried out to assist in further development of a rehabilitation and abandonment strategy for the Wolverine Creek tailings piles at the former Clinton Creek asbestos mine, northwest of Dawson City, Yukon Territory.

The scope of work covered in this report is as follows:

a) a hydrological review of the Wolverine Creek and Clinton Creek catchment areas based on available regional data to estimate extreme peak streamflows and annual flow-duration characteristics for the creeks;

b) an evaluation of the potential sediment carrying capacities of Wolverine and Clinton Creeks to assess how much tailings material may be transported downstream of the tailings piles and to identify areas where re-deposition of this sediment may occur.

Separate letter reports by Klohn Leonoff present the results of the other two work items described in Klohn Leonoff's December 11, 1984 letter, namely an assessment of the existing rock lined channel, and a stability analysis of the tailings pile.

The location of the tailings pile and the downstream reaches of the creeks studied in this report are shown on Drawing No. A-1009.

2. HYDROLOGICAL REVIEW

The catchment area of Wolverine Creek upstream of the tailings piles is estimated to be about 21.6 km^2. Clinton Creek downstream of the confluence with Wolverine Creek has a catchment area of about 140 km^2, increasing to about 200 km^2 at the confluence with the Forty Mile River. Water Survey of Canada streamflow data in the general mine region which were used in this study are summarized below:

TABLE 1

Available Streamflow Data

Station Name	Catchment Area (km^2)	Period of Record
Clinton Creek above Wolverine Creek	106	1964-65 (summers only)
North Klondike near the Mouth	1100	1974-83
Klondike River above Bonanza Creek	7800	1965-83
Forty Mile River near the Mouth	16600	1982-83

With the exception of the two partial years of record for Clinton Creek, there are no flow records available for small catchment area streams near the mine site.

For the purposes of this study, estimates of peak streamflows for the Wolverine Creek/Clinton Creek catchments were prepared based on the North Klondike and Klondike River records. For these rivers, unit flows in L/s/km^2 for average annual discharge and various return period flood events were plotted against catchment area. Flows for the upper Wolverine Creek catchment area of 21.6 km^2 were estimated by extrapolation and are listed in Table 2. The average annual flow was estimated to be 0.25 m^3/s, based on an estimated average annual runoff of 350 mm. The average or 2 year return period flood flow will probably result from snowmelt only and may have a duration of several days. More extreme events will probably result from rain-on-snow events and entail short durations of perhaps a few hours.

TABLE 2

Estimates of Flood Flows for
Upper Wolverine Creek Catchment Area

Flow Event	Unit Flow (L/s/km^2)	Flow (m^3/s)
2 Year Flood	220	4.75
50 Year Flood	570	12.3
100 Year Flood	650	14.0
200 Year Flood	740	16.0

Extreme flows for other locations in the Clinton Creek catchment were estimated in a similar fashion.

For relatively small catchment areas such as Wolverine and Clinton Creeks a wide variation in flow magnitudes may be expected during the year, ranging from very high magnitude but short duration flows, resulting from rainfall events,to low (or zero) flows during the coldest months of the winter. The Forty Mile River, with a catchment area of 16 600 km^2, has exhibited flows varying from zero to 1300 m^3/s with an average annual discharge of about 91 m^3/s in 1982 and 1983. Since its drainage area includes Clinton Creek, the Forty Mile River flow duration characteristics were used for the study. A unit flow duration curve was prepared and is shown on Drawing No. A-1010 which plots the ratio of (daily flow to mean annual flow) versus % time flow exceeded.

3. SEDIMENT TRANSPORT ANALYSIS

3.1 GENERAL

Klohn Leonoff have carried out a sediment transport analysis of Wolverine Creek, Clinton Creek and the Forty Mile River to assess the sediment carrying capacity of each. The purpose of the analysis was to estimate how much tailings material may be transported downstream of the tailings piles, and to identify areas where re-deposition of this sediment may occur.

3.2 SEDIMENT TRANSPORT MODEL

An interactive computer program known as MPMPC (developed by Simons, Li and Associates Inc.) was used to estimate potential sediment carrying capacities. MPMPC develops an applicable sediment transport capacity regression equation for a range of hydraulic conditions expected within a channel. The transport capacities are computed using a combination of the Meyer-Peter-Muller formula for bed load transport and Einstein's solution for suspended sediment transport. Required data inputs include the channel slope and hydraulic roughness, flow discharge intensity (discharge per unit width of channel), and a representative grain size distribution for the sediment. The potential annual sediment transport capacity of a stream channel at a particular location may be estimated using the results of the MPMPC program in conjunction with the annual flow duration curve applicable to the stream.

3.3 DATA UTILIZED

The MPMPC program was applied to representative channel sections in the existing rock lined channel across the tailings, lower Wolverine Creek, Clinton Creek below Wolverine Creek, and the Forty Mile River at the Clinton Creek confluence.

Channel gradients were estimated from available topographic maps and drawings, including the 1:50,000 NTS Map Sheet No. 116C/7. A profile along the entire channel length studied is shown on Drawing No. X-1011. Channel gradients range from 0.08 (8%) in the rock-lined section across the tailings pile to less than 0.001 (0.1%) for the Forty Mile River. Lower Wolverine Creek gradients are between 0.02 and 0.03 (2-3%). The initial 2 km of Clinton Creek below Wolverine Creek appears to have a slope of about 0.003 (0.3%) increasing to between 0.009 and 0.014 (0.9 to 1.4%) in the lower reaches.

Channel widths and roughness were estimated from available photographs, mapping, and data contained in previous reports[1], and observations made by Klohn Leonoff personnel during previous site visits. The representative grain size distribution for the tailings was taken from Figure B-3 contained in the 1978 Golder Associates Report and is summarized as follows:

TABLE 3

Tailings Grain Size Distribution

Particle Diameter (mm)	% Finer by Weight
20	100
2.0	60
0.2	20
0.06	10
0.02	5

The grain size curve indicates that 40% of the tailings material would be classified as fine to medium gravel, 50% as sand, and 10% as fine grained silt to clay sizes.

Channel discharge intensities were estimated to vary from less than 1 cfs/ft width (0.1 $m^3/s/m$) to about 30 cfs/ft (2.8 $m^3/s/m$) for Wolverine/Clinton Creeks, and up to about 90 cfs/ft (8.4 $m^3/s/m$) for the Forty Mile River.

3.4 RESULTS OF ANALYSIS

The MPMPC model indicates that, during an average flow year, all tailings material finer than coarse sand (60% of the total) that enters the upper lined channel section will eventually be transported to the Forty Mile River and beyond. The lined channel and the lower reaches of Wolverine Creek appear to have sufficient sediment transporting capacity

[1] Reports included: E.V.S. Consultants Ltd. (June 1981), Golder Associates Ltd. (July 1978).

to carry most of the gravel-sized tailings to the upper reaches of Clinton Creek. Downstream of the Wolverine Creek/Clinton Creek confluence, however, Clinton Creek does not appear to have sufficient capacity to transport medium gravels and only has limited capacity to transport fine gravel-sized material. The Forty Mile River cannot transport any gravel-sized material.

The table below summarizes estimated potential annual tailings transport capacities, and the percent of that total that would be sand sizes or finer, for various reaches of stream between the tailings piles and the Forty Mile River. Drawing No. A-1009 shows the locations of the different reaches. The annual capacities have been estimated by integrating the results of the sediment transport model and the flow-duration characteristics applicable to each reach.

TABLE 4

Potential Tailings Transport Capacities

Reach Number	Description	Potential Annual Capacity ($m^3 \times 10^6$)	Sand Volume* / Annual Volume
1	Rock-lined channel across tailings	0.85	92%
2	Lower Wolverine Creek	2.0	96%
3	Upper Clinton Creek	2.0	99.8%
4	Lower Clinton Creek	13.0	98%
5	Forty Mile River at Clinton Creek	790	100%

(* all material finer than coarse sand)

3.5 LIMITATIONS OF ANALYSIS

The results of the sediment transport analysis described above are discussed further in Section 4. The available data has necessitated making a number of assumptions which apply certain limitations to the results as discussed following:

a) the hydrological characteristics of the Clinton Creek watershed have been estimated from available regional data and are not based on site-specific measurements or data;

How about data from Clinton Creek at bridge?

b) sediment transport capacities determined in the MPMPC model are strongly dependent on channel discharge intensities and hydraulic roughness. Channel widths and roughness have been estimated from site photographs and descriptions without benefit of field measurements carried out at the specific reaches of interest. There are no sediment transport data available in the area with which to calibrate the model;

c) the 1"=200' mapping for Wolverine Creek and 1:50,000 scale NTS map for the area indicate a discrepancy in elevations and slopes of the Wolverine/Clinton Creek channels. The 1"=200' mapping indicates the confluence of the two creeks to be at about elevation 1190 ft, however the 1:50,000 scale topographic maps indicate the confluence elevation to be at about elevation 1270 ft. The 1"=200' scale mapping has been used to determine slopes for Wolverine Creek. Slopes for Clinton Creek downstream have been estimated based on the general trends indicated by the NTS maps and observations contained in earlier reports.

d) transport capacities listed in Section 3.4 are the total quantities of tailings that could be potentially carried by the streams assuming no other sediment is being transported. An unknown proportion of the annual capacities will be taken up transporting natural sediment. Actual rates of natural sediment transport in the streams, including wash load, suspended load and bed load, are probably much less than the potential capacities. The capacities should, however, give an indication of the relative order of magnitude of the annual rates at which natural sediment is being transported by the streams. Seasonal rates will vary widely depending on rates of streamflow.

e) the actual quantity per year of tailings that will be either transported through, or deposited, at different locations within the system depends on the rate at which tailings enter the Wolverine Creek valley from the tailings piles. It is estimated that the potential capacity of the lower rock lined channel is significantly greater than the probable rate of supply, unless there is a sudden slide failure of the tailings lobes into the valley bottom or if the stream should escape the rock lined channel.

The analyses carried out, although limited by available data, nonetheless allow a general appreciation of existing and possible future sediment transport processes at different locations within the Clinton Creek valley. The results are discussed further in the following section.

4. DISCUSSION

Based on the above limitations it is possible to anticipate the general nature of changes that may occur downstream of the Wolverine Creek tailings piles. The anticipated changes, however, depend on the probable short and long term behaviour and stability of the tailings piles which comprise the major source of additional potential sediment loading to the downstream creeks and rivers. The discussion in Sections 4.1 and 4.2 following describes possible downstream changes for two potential modes of behaviour of the tailings:

1) gradual downslope movement of the tailings continuing at a relatively slow or uniform rate;

2) the tailings pile undergoing one or more sudden and rapid slide failures into the valley bottom.

4.1 GRADUAL TAILINGS PILE MOVEMENT

Assuming that the rate of tailings encroachment into the valley either remains relatively slow and uniform or decreases with time, and assuming that the existing rock-lined channel does not fail, the following changes to the existing Wolverine Creek and Clinton Creek channels are anticipated:

a) tailings material will continue to accumulate in the area of the small lake upstream of the south tailings lobe. If the rock lined channel continues to operate as it has over the past six years it will serve to control the elevation and limit the slope of the upstream channel. As the lake fills with tailings, especially gravel/coarse sand sizes, it will be moved progressively further north. Across the east side of the valley a new gravel lined channel, perhaps braided in appearance, may form with a relatively flat slope of perhaps 0.003 to 0.005.

b) some gravel-sized tailings may accumulate in the lower lined channel (Reach No. 1) within the voids between the riprap lining. Over time, the net result may be a gradual decrease in the hydraulic roughness of the channel, thereby increasing the potential flow and sediment carrying capacity of the channel without any significant adjustments to the longitudinal slope;

c) lower Wolverine Creek (Reach No. 2) may experience some local deposition of gravel sizes during periods of decreasing streamflows following snowmelt or rainfall-induced high flow events. No significant long-term aggradation of the streambed is expected in this reach;

d) gravel-sized material entering upper Clinton Creek (Reach No. 3) from Wolverine Creek will probably deposit downstream of the confluence, resulting in a general raising or aggradation of the streambed as happened after the 1974 failure. Due to the lower longitudinal slope, this reach has only a limited capacity to transport gravels, and the rate of bed aggradation will depend on the supply rate of gravel from the tailings piles. Over the long term, some bed aggradation may utimately extend as much as 2 km downstream of the confluence, to the point where the natural channel gradient increases to about 1% (end of Reach No. 3);

e) tailings material transported through Reach No. 3 will probably also be transported through Reach No. 4 (lower Clinton Creek) to the Forty Mile River. Some minor deposition of coarser material may occur in local backwater areas, local scour holes, or areas subject to debris blockage and local ponding as streamflows recede. On average over the long term no major changes to the channel regime is anticipated in this reach;

f) at the confluence with the Forty Mile River, Clinton Creek has formed a natural fan of gravel and cobble-sized material, confirming that the Forty Mile River has little or no capacity to transport coarser material. Any gravel-sized tailings reaching the confluence will probably deposit on or near the fan. Based on the potential sediment transporting capacity of the Forty Mile River (Table 4), it appears that all silt sizes and most sand-sized tailings reaching the confluence will, on an annual basis, be transported downstream by the Forty Mile River to the Yukon River.

4.2 RAPID TAILINGS PILE MOVEMENT

The stability analysis study of the tailings pile carried out by Klohn Leonoff and described in a separate report dated February 28, 1985 indicates that there is a possiblity of the tailings pile undergoing a sudden and rapid slide failure downslope into the Wolverine Creek valley bottom.

Such an occurrence would probably block the inlet to the lower rock lined channel and could raise the level of the present tailings deposit in the valley bottom by up to 20 m (70 ft) over a length of about 150 m (500 ft). The existing small lake would be displaced to the north and may, in time, fill with natural runoff from upper Wolverine Creek to a level and volume significantly greater than is contained at present. When the water level reaches the top level of the failed tailings, the lake will overflow and Wolverine Creek will begin to form a new channel across the tailings without the benefit of the grade control presently provided by the lower rock lined channel. A failure of the rock-lined channel regardless of rates of movement of the tailings piles could also result in a new unlined channel being formed across the tailings. The new channel would progressively erode down through the tailings. Initial rates of erosion and downcutting in the new unlined channel will be rapid but may decrease with time as the channel becomes armoured with the larger tailings gravels. During high flow periods the rates of transport of all sizes of tailings away from the tailings pile will be much higher than would occur under the gradual tailings pile movement scenario discussed previously since the sediment supply would be essentially unlimited in the upper reaches. Depending on the degree of armouring, the developing channel will probably attempt to attain a new stable overall slope of 2-3%, similar to the natural slope of lower Wolverine Creek.

Large quantities of gravel would be transported to upper Clinton Creek where, as a consequence of this reach's limited gravel carrying capacity, gravel deposits will form across the valley bottom in the area of the Wolverine Creek confluence and downstream. Based on the geometry of the overall channel profile these gravel deposits could accumulate, in the long term, to as much as 10 m deep in the area of the confluence and may extend downstream over a length of about 2 km.

Local sand deposition in lower Clinton Creek (Reach No. 4) may be more pronounced on a seasonal basis, however on an annual basis this reach should have sufficient transporting capacity to maintain the present regime of the creek. Sands and silts reaching the Forty Mile River should, based on the relative potential transport capacities, be carried away by the Forty Mile to the Yukon.

5. CONCLUSIONS

Based on the hydrologic, hydraulic, and sediment transport analyses described in this report, the following general conclusions may be drawn:

1) the existing rock lined channel, lower Wolverine Creek and lower Clinton Creek (Reach No.s 1, 2 and 4) can transport all sizes of the tailings material;

2) the upper reach of Clinton Creek below Wolverine Creek (Reach No. 3) has a limited capacity to transport gravel sizes;

3) the Forty Mile River cannot transport sediment larger than coarse sand but has a potential annual sediment transporting capacity significantly higher than Clinton Creek for sand sizes and finer;

4) continued gradual downslope movement of the tailings pile will probable result in some aggradation of gravel in upper Clinton Creek but only minor local depositions of tailings in other reaches;

5) a sudden or rapid slide failure of the tailings piles into Wolverine Creek could eventually result in significant bed aggradation in lower Wolverine

and upper Clinton Creeks. Over the long term no significant accumulation of sediment is anticipated in lower Clinton Creek or the Forty Mile River over and above existing natural processes.

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April 11, 1985
File: 30-47-2A

Klohn Leonoff Consulting Engineers
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Attention: Mr. Peter Lighthall, P.Eng.

Dear Mr. Lighthall,

RE: CLINTON CREEK ASBESTOS MINE AQUATIC IMPACT ASSESSMENT

In accordance with instructions from Brinco Mining, Norecol Environmental Consultants Ltd. has reviewed existing information regarding the tailings pile failure at the Clinton Creek asbestos mine and made an assessment of the potential impacts on the fisheries resource in Clinton Creek. The following report provides background information, identification of the fisheries resources and a preliminary assessment of the impacts on the aquatic environment.

BACKGROUND

The Clinton Creek asbestos mine is located in the northwest corner of the Yukon Territory, 97 km northwest of Dawson City. The mine is situated on Clinton Creek which drains into the Fortymile River, 4.8 km from its confluence with the Yukon River. The open pit mine operated from 1968 to 1978, when economic ore reserves were exhausted. Waste rock overburden, consisting mainly of argillite, was dumped on the south slope of the Clinton Creek valley across Clinton Creek forming a small lake (Hudgeon Lake). Dry tailings, consisting mainly of serpentine material, was dumped on the west side of Wolverine Creek, a tributary of Clinton Creek downstream of Hudgeon Lake. In the spring of 1974 the south lobe of the tailings dump failed, blocking Wolverine Creek. As a result a small lake was impounded in Wolverine Creek (Wolverine Lake) upstream of the toe of the slide. After the failure of the south lobe of the tailings dump a north lobe was established. The north lobe is also moving downslope and encroaching on Wolverine Lake.

Continued . . .

Subsequent to the failure of the tailings piles, concerns were expressed regarding the effects on the aquatic environment in Clinton and Wolverine creeks, and the potential hazard of increased asbestos on downstream domestic water supplies. In response to these concerns environmental studies were conducted by the Environmental Protection Service (1978) in 1974 and 1975, and by EVS Consultants Ltd. (1981) in 1980. In addition, Klohn Leonoff Consulting Engineers conducted stability studies on the tailings piles and waste dump (Klohn Leonoff, 1984a, 1984b) and conducted sediment transport analyses on Wolverine and Clinton creeks to develop a rehabilitation and abandonment strategy (Klohn Leonoff, 1985). In the sediment transport study, Klohn Leonoff discuss two potential scenarios for behaviour of the tailings: 1) gradual downslope movement at a slow, uniform rate; 2) one or more rapid slide failures into the valley bottom. Our analysis also assumed that Hudgeon Lake will remain in its present state.

FISHERIES RESOURCES IN CLINTON CREEK

Clinton Creek is utilized by Arctic grayling (*Thymallus arcticus*), juvenile chinook salmon (*Oncorhynchus tshawytscha*), longnose sucker (*Catastomus catastomus*), lake whitefish (*Coregonus clupeaformis*), round whitefish (*Prosopium cylindraceum*) and sculpins (EPS, 1978; EVS Consultants, 1981). Arctic grayling appear to inhabit Clinton Creek year-round for rearing, adult maturation and spawning. Grayling are known to inhabit Hudgeon Lake and are able to migrate up through the lake outflow culverts during high flow. Juvenile chinook rear in lower Clinton Creek, but probably originate from the Fortymile River, since larger water courses are preferred by chinook for spawning. Other species indigenous to the Yukon River system also appear to use Clinton Creek on a seasonal basis.

Previous physical alteration of the stream channels has apparently been relatively localized. Small lakes have been formed in both Clinton Creek, by the waste rock dump, and Wolverine Creek, by the failing tailing piles. In Clinton Creek physical alteration of the stream channel extends for approximately 2.8 km downstream from the waste rock dump. The upper 0.5 km of this section is channelized for erosion control across the toe of the waste dump and is dominated by a narrow, steep canyon strewn with boulders and bedrock. Downstream of this are braided, unstable channels through washed rock. The area is generally devoid of riparian vegetation due to bank erosion. The remainder of Clinton Creek is relatively undisturbed. In Wolverine Creek a rock-lined channel, devoid of vegetation, carries the stream over the failed south tailings lobe. Downstream, the streambed consists of washed tailings.

Clinton Creek was found to support the greatest abundance of grayling and juvenile chinook in the small canyon below Hudgeon Lake (EVS Consultants, 1981). It appears that this unique lake habitat has enhanced the fish habitat capability. The lake is an abundant source of *Daphnia*, which was found to be important to the diet of grayling captured just below the lake. The lake also provides extensive overwintering potential for grayling. Another reason for the abundance of fish in the canyon is the extensive instream boulder cover which provides greater habitat diversity than elsewhere in the stream. Since the EVS study the channel has been further modified to prevent erosion and downcutting. These changes may have altered the fish habitat and population characteristics.

It is not clear whether the apparent absence of fish in Wolverine Creek is a result of fish habitat loss due to the failure of the tailings dump or the presence of culverts at the mouth.

FISHERIES IMPACT OF TAILINGS PILE FAILURE

The impact of tailings pile failure on Clinton Creek and downstream waters was made considering the two failure scenarios described by Klohn Leonoff (1985). The first is a gradual downslope movement into Wolverine Creek resulting in continuous erosion and downstream transport of the tailing material. Klohn Leonoff (1985) predicted that at the present rate of encroachment of the tailings dump into Wolverine Creek coarse sediment will be deposited in Clinton Creek causing bed aggradation as much as 2 km downstream. The rate of bed aggradation will depend on the supply rate of material from the tailings piles. It is presumed that of the movement, subsequent erosion and associated high suspended solids concentrations would likely occur during spring high flow periods with reduced erosion and concentrations occurring in lower flow periods. The second scenario was a rapid failure with most of the tailings material entering the creek in a relatively short time period.

Klohn Leonoff (1985) predicted that a rapid slide failure of the tailings dump could cause coarse sediment to be deposited as much as 10 m deep over a 2 km section of Clinton Creek. A rapid failure of the tailings would cause prolonged elevated levels of suspended solids, which would be deposited over the length of Clinton Creek during low flows. Klohn Leonoff state that material finer than coarse sand would eventually be transported to the Fortymile River.

General Water Quality

EPS found elevated levels of calcium, magnesium, iron, manganese, potassium and hardness in Clinton Creek, but the levels were not elevated to the point that would be harmful to aquatic organisms. This is expected to remain the case, having no impact on aquatic resources.

Suspended Solids and Asbestos

Clinton Creek experiences asbestos fibre loading from the waste dump and the tailings piles in Wolverine Creek. The Environmental Protection Service (1978) conducted a series of bioassays using juvenile coho salmon to determine the possible effects of waterborne asbestos fibres in water from Clinton Creek. The samples were found to be non-toxic at 100% concentration over 96 hours, 8 days and 16 days. Subsequent histological analysis indicated some gill tissue damage had occurred in the experimental fish, but the significance of the finding was unknown.

Fish are known to accumulate asbestos fibres in the kidney, liver and pancreas. Metsker (per. comm.) studied various species of fish in the Yukon River for asbestos fibre accumulation and found that while some cellular changes (mechanical damage) were evident, no carcinogenic effects were observed. He indicated that there are no definitive studies which link asbestos in fish tissues to fish disease. Therefore, the effects on fish exposed to asbestos fibres would be similar to fish exposed to other water borne particles or suspended solids such as those from placer mining (McLeay et. al., 1983). The slow failure scenario would not be expected to affect fish other than causing slight gill damage as described by EPS (1978) and McLeay et al. (1984) and found to occur in the fish exposed to Clinton Creek water (EPS, 1978). However, a rapid failure of tailings would cause extreme levels of suspended solids in Clinton Creek and would be expected to cause significant fish deaths by the clogging of gills and suffocation of fish.

Habitat Alteration From Sedimentation

Studies carried out by EVS Consultants (1981) indicated some degradation of habitat had occurred downstream of the tailings piles in Clinton Creek. The piles have continued the process of slow failure since the earlier study and as a result are a constant source of materials for downstream transport and deposition in Clinton Creek. The effect of this downstream transport and deposition since 1980 is not known but may have alienated some additional portion of Clinton Creek from productive fish habitat. Klohn Leonoff (1985) predict that as much as 2 km of the Clinton Creek streambed will eventually be aggraded (sedimented) in this process. It seems likely that some gradient of effect may also occur downstream of the 2 km section of streambed that would be covered with tailings material.

Sediment deposition is known to cause reduction in fish food organisms which would be of particular concern since food availability may be the limiting factor for fish in Clinton Creek during late summer (EVS Consultant, 1981). This would be of more concern in areas removed from Hudgeon Lake where food supplies are not substantially augmented by zooplankton from the lake.

Sediment deposition also reduces rearing and spawning habitat for fish and will reduce survival of fish eggs deposited in or on the gravel. The levels of substrate sediment required to cause such effects may be relatively small (i.e. survival of salmonid eggs has been reduced by sediment levels of less than 10% in the substrate).

The second scenario of rapid tailing pile failure would cause the deposition of sediment throughout Clinton Creek below Wolverine Creek. This would significantly impact the fisheries capability of the stream by severely reducing fish habitat and fish food organisms until the natural transport processes were able to remove the accumulated sediments.

The sudden failure of the tailing piles would change the use of lower Clinton Creek, downstream of Wolverine Creek, from a rearing, migratory, spawning habitat to more restricted use making it primarily suitable for migratory purposes only. The effect of a sudden failure would likely be felt for more than one year but would probably be flushed from the system in succeeding freshet periods. The particle sizes found in the tailing material would indicate that they may be subject to flushing from the system in high flow periods during subsequent years. Although the time period is not known, there is potential for recovery of the stream.

ASBESTOS LEVELS IN DRINKING WATER

Asbestos fibre concentrations in the Clinton Creek drainage was found to be relatively high after the tailings pile failure. However, fibre concentrations in downstream waters subsequent to the failure were of the same magnitude as other Yukon Territory and British Columbia watersheds with comparative geology. Fibre concentrations in Clinton Creek have decreased downstream of the mine since the initial failure probably as a result of stabilization and erosion control measures carried out by the company. Water sampling programs were conducted by EPS and EVS Consultants but could find no evidence of elevated asbestos concentrations in the Fortymile or Yukon rivers attributable to Clinton Creek. These rivers were found to carry naturally high concentrations of asbestos fibre. It is probable that only the most severe asbestos loading in Clinton Creek would be detectable in the Fortymile River, due to the relative size of the water courses.

Domestic water use of the lower Fortymile River is not known but is thought to be minimal since the town of Forty Mile is abandoned and the town of Clinton Creek was closed with the mine. In any case, no studies have linked asbestos ingestion to illness in humans (Shapiro, pers. comm.).

CONCLUSION

The review of information has indicated that lower Clinton Creek (below Wolverine Creek) contains several species of fish and is of low to moderate productivity. The effect of tailings pile failure on the fisheries capability of this drainage depends on the speed of the failure. A slow failure will eventually sediment the stream bottom for 2 km immediately downstream of Wolverine Creek and may also affect a portion of the creek further downstream. The effect on the fish populations within the area that maybe affected by slow tailing failure is uncertain. It may or may not be significant considering that fisheries resources have been enhanced as a result of Hudgeon Lake and because the rate of sediment accumulation or flushing is uncertain. A rapid failure of the tailings pile will significantly affect all of Clinton Creek downstream of Wolverine Creek making it of limited fisheries value and significantly affecting fish populations below Wolverine Creek. Flushing of the tailing material may occur during subsequent freshet periods offering the potential for some recovery of the stream.

If you would like clarification of any of the impacts I have identified or want any further explanation of my interpretations, I would be pleased to discuss them with you. I have also attached a list of the references and personal communications used in the presentation.

Yours truly,
Norecol Environmental Consultants Ltd.

J. G. Malick

J. G. Malick, Ph.D.
Head, Aquatic Sciences

JGM:rm

Attachment

cc: Brinco Mining

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